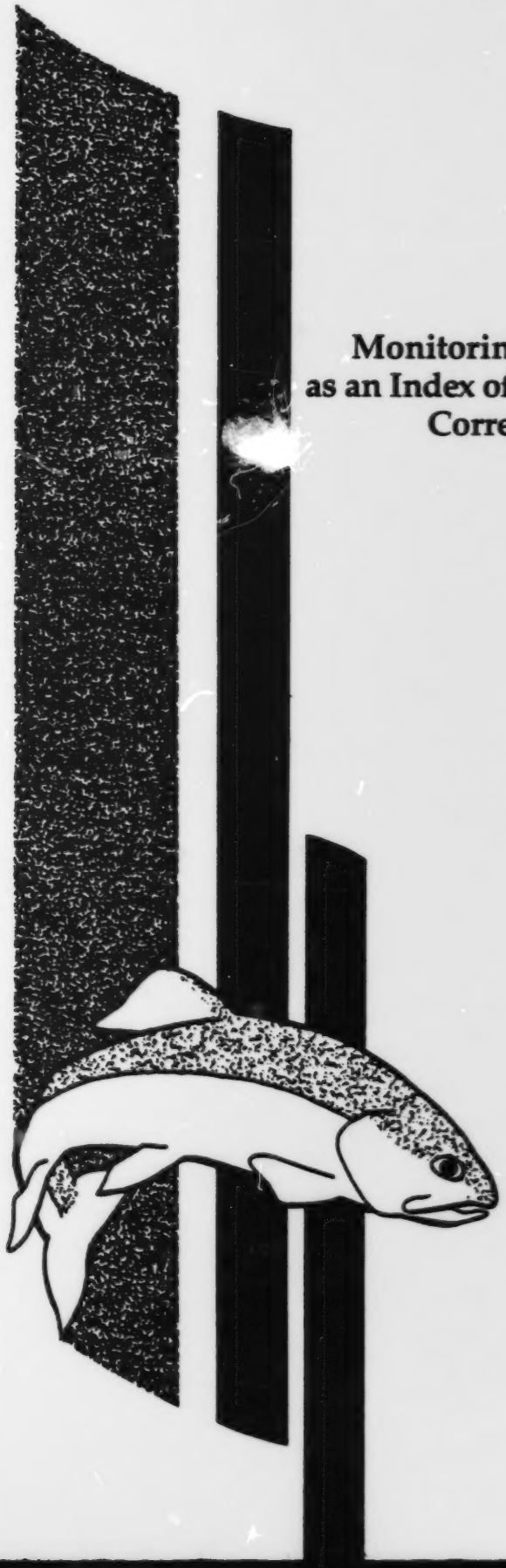

Monitoring Steelhead Trout at the Keogh River as an Index of Stock Status and Smolt-to-Adult Survival: Correlations with Other Data Sources

by

B.R. WARD
J.C. WIGHTMAN

FISHERIES MANAGEMENT REPORT No. 95

1989

Province of British Columbia
Ministry of Environment

Fisheries Management Reports are documents relevant to sportfish management in British Columbia, but for various reasons were not submitted for journal publication and are not generally reviewed by referees outside the Fisheries Branch.

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Fisheries Management Report No. 95
1989

Canadian Cataloguing in Publication Data

90-00641/

Ward, B. R. (Bruce R.), 1952-
Monitoring steelhead trout at the Keogh River as an index of stock status and smolt-to-adult survival

(Fisheries management report, ISSN 0705-5390 ; no. 95)

Issued by Fisheries Branch.
Bibliography: p.
ISBN 0-7726-1033-9

1. Steelhead (Fish) - British Columbia - Keogh River. 2. Fish populations - British Columbia - Keogh River. I. Wightman, J. C. II. British Columbia. Ministry of Environment. III. British Columbia. Fisheries Branch. IV. Title. V. Series: Fisheries management report (British Columbia. Fisheries Branch) ; no. 95.

SH167.T86W27 1989 639.3'755 C89-092264-0

ABSTRACT

Ward, B.R., and J.C. Wightman. 1989. Monitoring steelhead trout at the Keogh River as an index of stock status and smolt-to-adult survival: correlations with other data sources. Prov. of B.C. Fish. Manage. Rep. No. 95. 21p.

Population estimates of adult steelhead trout, obtained at the Keogh River on northern Vancouver Island, were compared to catch statistics and underwater fish counts collected elsewhere in British Columbia. Also, survival rates from smolt-to-adult for Keogh steelhead were compared to rates obtained at another research station, Snow Creek, Washington. Similar trends were found in all comparisons. Angler catch of wild fish in the Keogh River and neighbouring streams was closely correlated with the run size estimates of the Keogh River adult steelhead (n=13). Annual catch of wild fish on Vancouver Island followed a similar trend as the winter run of the Keogh but the statistical correlation was weak unless years were sequentially paired (n=6). Representative winter-run streams to the south displayed catch statistics that weakly correlated with Keogh run sizes unless also sequentially paired. Of the larger rivers, there was close correlation between Nimpkish River catch, on northern Vancouver Island, but not Cowichan River catch on southern Vancouver Island, and Keogh run size. Underwater counts of steelhead in two summer-run streams had similar trends but failed to correlate with Keogh stock size, even with years paired. Survivals at the smaller Snow Creek in northwest Washington were similar to survivals obtained at the Keogh in 4 of 6 years, and differences in the other two years were possibly due to smolt size, handling effects and anomalous oceanographic conditions. Implications for future stock monitoring are discussed including the effects of introductions of hatchery fish and regulation changes on the validity of use of results from the Steelhead Harvest Analysis for interpretation of steelhead abundance.

ACKNOWLEDGEMENTS

Keogh research has been conducted under the stimulating direction of P.A. Slaney. We thank all field and support staff, including Dr. A.F. Tautz, as well as all regional biologists for their encouraging support in continuing research at the Keogh River. S. Billings kindly summarized and provided the B.C. catch statistics for the 1976 to 1988 period. We are indebted to Tom Johnson and Randy Cooper, Washington Department of Wildlife, for allowing us to use their survival data from the research ongoing at Snow Creek, Washington. Pat Slaney reviewed a draft and his editorial comments were most welcome and helpful. We are also grateful for the editorial comments of G. Reid.

INTRODUCTION

Long-term studies of wild fish populations by use of counting fences have been emphasized as important for detection of trends (Narver 1982). Narver noted there were only three such streams in the Pacific northwest: Carnation Creek, Snow Creek, and the Keogh River. Since then, interest in the use of several index streams to monitor coho salmon (Oncorhynchus kisutch) production has grown and the Federal Department of Fisheries and Oceans has commenced research on a number of B.C. coastal systems (Bocking et al. 1988). Snow Creek continues to provide results on steelhead Oncorhynchus mykiss (formerly Salmo gairdneri) population trends in northwest Washington (Loch et al. 1988). Run sizes are relatively low at Snow Creek and Carnation Creek; at the latter the emphasis was on documenting the effects of logging (Hartman 1982). Other fences on two other B.C. streams (Big Qualicum and Little Campbell rivers) have provided short-term estimates of steelhead adults and smolts but they were not located near the river mouth (Peterson and Lyons 1968, Rempel et al. 1984). In British Columbia, the Keogh River on northern Vancouver Island (Fig. 1) remains the main source of trend data on steelhead stock abundance.

Two of the goals of research at the Keogh River were to examine egg-to-adult survival and develop time-series data on a steelhead population. Ward and Slaney (1988) showed how time-series data from the Keogh could be utilized to understand some of the flucuations in wild populations. The Keogh River had been selected during the formative stages of the Salmonid Enhancement Program to research the life history and ecology of steelhead as well as Dolly Varden Salvelinus malma (Smith and Slaney 1980), and coho salmon (Irvine and Ward 1989, Johnston et al. 1986, 1987). In addition, several experimental enhancement techniques were developed and evaluated, including habitat improvement (Ward and Slaney 1981, Slaney et al. 1986, Perrin et al. 1987) and lake-pen steelhead culture (Slaney and Harrower 1981, Ward et al. 1990 in prep.). In recent years, the emphasis shifted to monitoring the trend in survival of steelhead smolts to their return to the river as adults.

An index stream must reflect fish population trends in other river systems to be of management value (Symons and Waldichuk 1984). The purpose of this report is to examine the feasibilty of the Keogh River as an "index stream", i.e., indicator of stock status, after thirteen years of data collection. Estimates of the adult steelhead populations of the Keogh River were used in correlation analyses with catch data from local rivers, typical winter-run streams on Vancouver Island, the wild catch on Vancouver Island, and underwater counts from two summer-run streams. Six years of estimates of survival of steelhead smolts to return at fish fences at the Keogh River and Snow Creek were also compared.

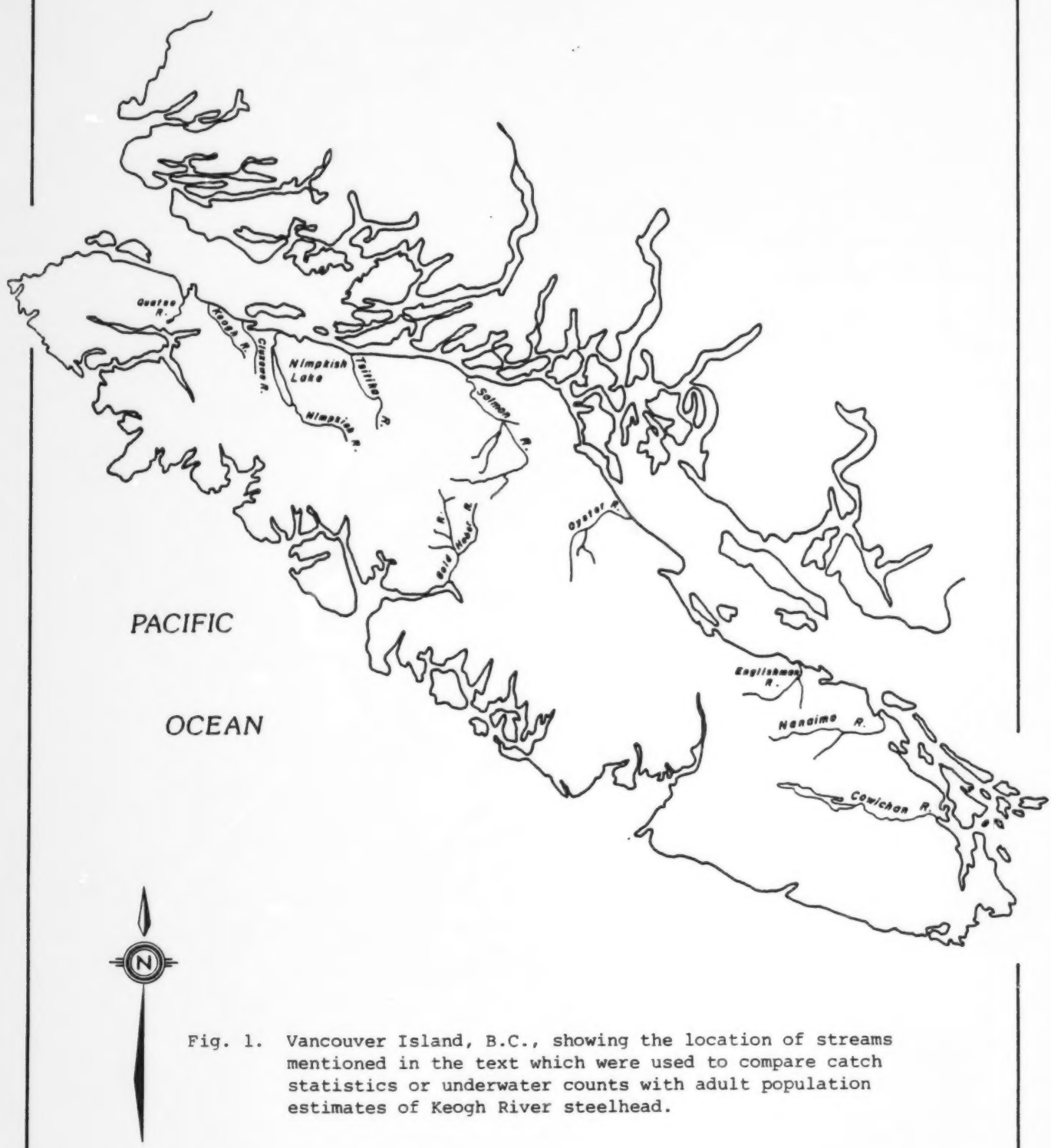

Fig. 1. Vancouver Island, B.C., showing the location of streams mentioned in the text which were used to compare catch statistics or underwater counts with adult population estimates of Keogh River steelhead.

METHODS

Description of Study Streams

The Keogh River was selected as a study stream during the mid-1970's primarily for the ability to trap migrant adults and smolts, the accessibilty of the site, the low angler use, and the estimated abundance of wild winter-run steelhead. The trap and stream are described elsewhere (Mottram 1977; Perrin and Johnston 1985; Ward and Slaney 1979, 1981, 1988). Like most Vancouver Island streams, it is relatively short (33 km) with moderate gradient except in the limited headwater area. Rainfall primarily controls discharge.

Winter-run steelhead streams for which catch statistics were compared included, from south to north: the Cowichan, Nanaimo, Englishman, Oyster, Salmon, and Nimpkish Rivers - all of which are located on the east coast of Vancouver Island (Fig. 1). Age and life history of these steelhead populations were described by Hooton et al. (1987). The Tsitika and Gold Rivers are summer-run streams (Hooton et al. 1987), located on the east and west coast of Vancouver Island, respectively (Fig. 1).

Sources of Data

Keogh steelhead run sizes were determined from 1976 to 1988 by Peterson population estimates (Ricker 1975) based on capture and marking of upstream migrant adults and capture of kelts in their downstream migration to examine them for marks. Details are provided in Ward and Slaney (1988) and Ward et al. (1989 in press), as are the estimates of marine survival rates derived from enumeration of the smolt migrants and returns of adults from a given smolt year.

The annual Steelhead Harvest Analysis, conducted since 1966, provided angler-catch statistics. Billings (1988) describes the method by which anglers were surveyed by a mail-out questionaire. The survey period extended from April 1 to March 31 in each year for reporting purposes, which placed the April and May portion of the winter-run catch in the subsequent year's report. For example, the catch during April and May, 1989, will be reported as part of the 1990 winter-run season's results. The catch of wild steelhead comprised kept and released fish, with mandatory release of all wild fish from Dec. 1 to March 1 on Vancouver Island after 1981, followed by elimination of the harvest of wild fish after 1985. There is no separation of summer- and winter-run catch in the Steelhead Harvest Analysis.

Underwater surveys were conducted annually since 1975 and 1976 on the Gold and Tsitika Rivers, respectively, to determine relative escapement of summer-run steelhead.

These swims by divers in dry suits occurred in the period from July to October, or (in the last five years) from August to September, when the majority of returning adults have entered the streams. The survey in each stream was designed to sample most of the prime habitat in which adult steelhead could be found over the summer (mainly deep pools and boulder areas).

Divers' methods were consistent. Streams surveyed in the summer were low in flow and relatively clear, providing visibility for several meters. Swims were conducted from mid-morning to mid-afternoon, with generally the same crew. In some cases, areas sampled were later beach-seined and counts compared, and there was close agreement (J.C. Wightman, data on file). The swim count method involved two 2-person teams, with each team sampling half of the survey section. Team members swam abreast and attempted to view the entire stream width. Individual counts were compared regularly, and a pool was re-sampled if counts differed. A known number of marked fish was not used to estimate population size as reported by Slaney and Martin (1987). Until such a calibration is completed, it is uncertain what proportion of the total population was enumerated.

Statistical Procedures

Relationships between anglers' catch, underwater counts and population estimates of Keogh adults were examined by correlation analyses (SAS Institute 1985). Data used in the correlation analyses of this paper are included as Appendix 1. First, we examined the relationship between the steelhead population estimate and the catch of Keogh steelhead in that season. We then determined the correlation coefficients of the population estimates and Vancouver Island catch, catch of steelhead in representative winter-run streams, and catch of steelhead in local streams. The catch and population estimates were also combined in two-year (sequentially paired) blocks from 1977 to 1988 and the relationships examined. This was done because the questionnaire period overlapped two seasons and steelhead ocean age varies mainly over two years (i.e., fish generally return after 2 or 3 years in the ocean, and proportions may vary by population).

Survival of fish during the period of ocean residence was compared using smolt counts and survival estimates from the Keogh River and Snow Creek. A description of Snow Creek, Washington, is in Loch et al. (1988), along with tabled smolt and parr yields from 1978 to 1984. Survival rates for Snow Creek smolts were provided by R. Cooper and T.H. Johnson (Washington Department of Wildlife, Port Townsend). The fish trapping facility at Snow Creek is located 1 km upstream of the mouth of the Creek, and has been

reported as 90-100% efficient at smolt capture (Loch et al. 1988). All adult steelhead are captured at the fence as they migrate upstream at Snow Creek except for a proportion estimated visually that spawn below the fence. Methods of calculating survival rate during ocean residence of Keogh River steelhead are described in Ward and Slaney (1988) and Ward et al. (1989 in press, 1990 in prep.). In brief, returns from a smolt year (the smolt yield of a given year comprised of several freshwater age classes) were determined by aging adult steelhead from scales removed during upstream trapping, and by then partitioning the population estimate by the age composition, based on the number of years spent in salt water, to determine the year of smoltification.

RESULTS

Correlation with Local Streams

The angler catch in the Keogh River and local streams correlated positively with the Keogh population estimates 1976 to 1988 (Fig. 2). Keogh run size and catch was significantly correlated ($r=0.79$, $p<.01$), as was Keogh run size and the combined catch in the neighbouring Quatse and Cluxewe Rivers ($r=0.75$, $p<.01$). For the last five years, Keogh population estimates and Keogh angler catch have followed closely, with the reported catch averaging 41% (range between 20% and 54%) of the spawning population. The estimated harvest rate was much lower, approaching zero. This represents a shift from the period of 1976 to 1983 where the estimated catch rate averaged about 17% (range between 11% and 26%). In all years but two (1982 and 1987), the combined catch in the Quatse and the Cluxewe Rivers was greater than the catch in the Keogh River. The catch of winter-run steelhead in northern Vancouver Island streams appears to vary in the same direction most years, and the catch variation year-to-year follows the pattern of the estimated run sizes of the Keogh River.

Representative Winter-run Streams

We combined the catch from four streams to represent the winter-run catch on Vancouver Island - the Englishman, Oyster, Nanaimo, and Salmon Rivers (Fig. 2). Two large streams, the Cowichan and the Nimpkish Rivers, were also selected to compare their catch statistics (Fig. 3) with Keogh population estimates. Catch from the Nimpkish River, on northern Vancouver Island, was highly correlated with Keogh population estimates ($r=.61$, $p<.05$), particularly when the high leverage of the 1987 point was excluded from the analysis ($r=.81$, $p<.01$). Peaks in abundance of fish in the

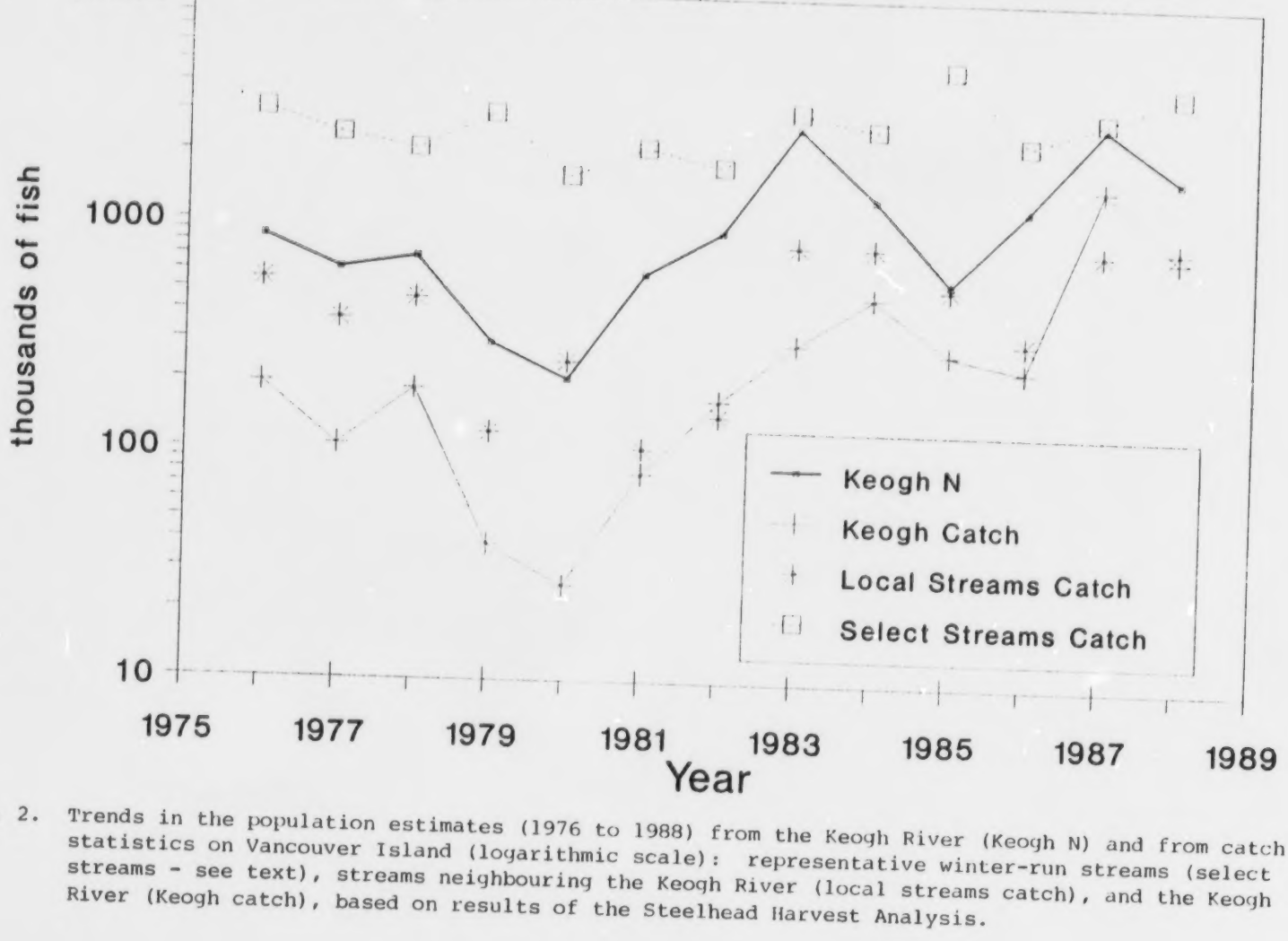

Fig. 2. Trends in the population estimates (1976 to 1988) from the Keogh River (Keogh N) and from catch statistics on Vancouver Island (logarithmic scale): representative winter-run streams (select streams - see text), streams neighbouring the Keogh River (local streams catch), and the Keogh River (Keogh catch), based on results of the Steelhead Harvest Analysis.

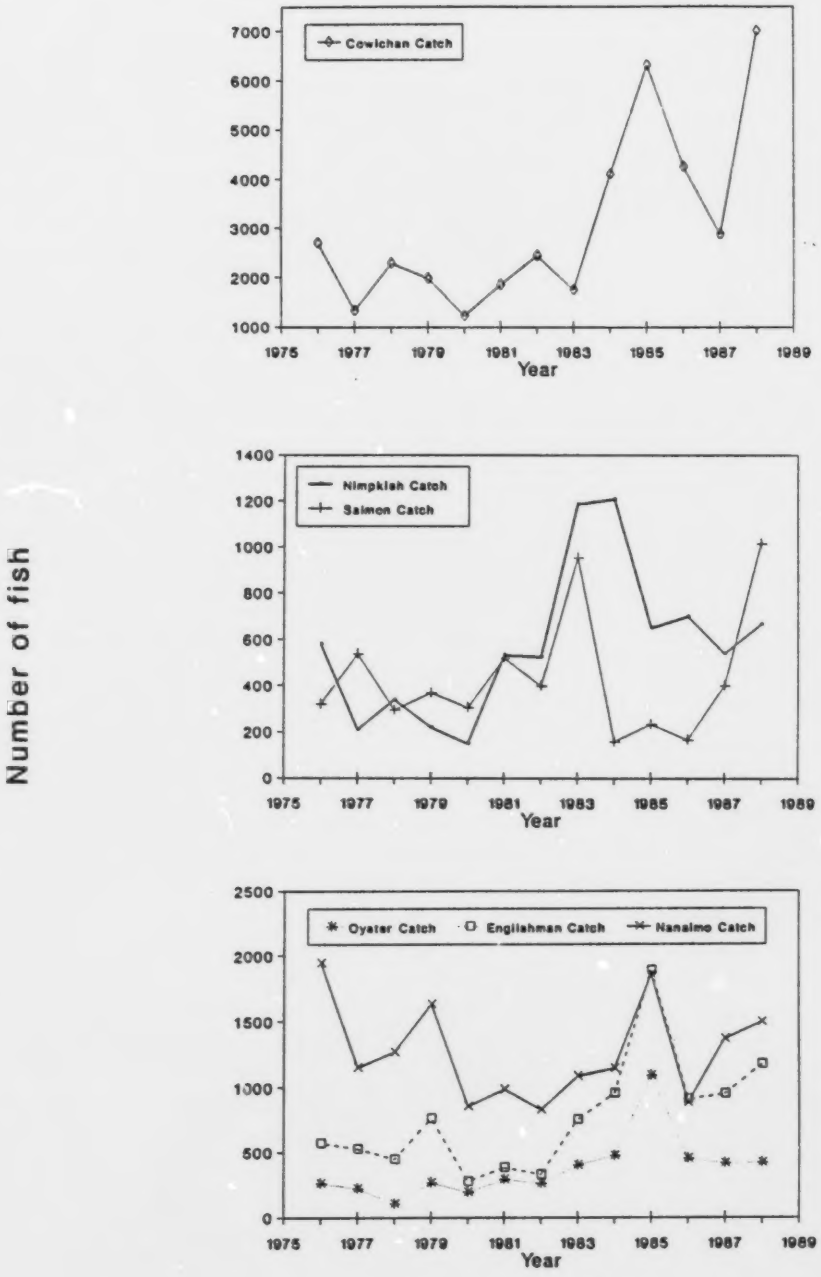

Fig. 3. The steelhead catch statistics (1976 to 1988) derived from the Steelhead Harvest Analysis for representative winter-run streams on Vancouver Island used to compare with Keogh River population estimates.

catch at the Cowichan River (Fig. 3), on southern Vancouver Island, were largely one or two years later than peaks in abundance of spawners at the Keogh River (Fig. 2). There was no correlation ($r=.17$, $p>.05$), even when data was lumped by two year blocks, as above ($r=0.57$, $p>.05$), unless the 1985-1986 point was excluded ($r=.90$, $p<.05$). Similarly, the combined catch in the smaller winter-run streams was uncorrelated ($r=.25$, $p>.05$) unless years were lumped in two year blocks and the 1985-1986 data point excluded ($r=.89$, $p<.05$).

Region 1 Catch

Catch on Vancouver Island (Fig. 4) and Keogh River steelhead run estimates were correlated when sequentially paired (1977 to 1988). The exception to this correlation was the possible outlier (Draper and Smith 1966) of the 1985-1986 data point ($r=.77$, $p=.07$ with the 1985-1986 datum; $r=.99$, $p<.001$ without it), where Keogh average run size had declined while the catch increased. Averaged over four years, both Keogh run size and Vancouver Island catch displayed an increasing trend. There was no correlation between the individual estimates of the population size of the Keogh River and the total angler catch of wild steelhead on Vancouver Island ($r=0.22$, $p>.05$). The Vancouver Island catch, comprised of both summer-run and winter-run fish, declined from 1975 to 1980 but increased in the next half-decade (Fig. 4). Although spawning population size in the Keogh River has generally been above average throughout the 1980's, increases and declines in individual years have not continuously followed the pattern of catch for Vancouver Island. In the year-to-year comparison, the 1985 data was the poorest match, where catch was high relative to the run size at the Keogh River. With the removal of the 1985 data, catch on Vancouver Island and Keogh run strength were highly correlated ($r=.66$, $p<.05$). Interestingly, Keogh catch (including 1985) correlated with Vancouver Island catch ($r=.58$, $p<.05$).

It was of interest to examine trends in catch province-wide. Catch statistics from the entire province also displayed the trend of a declining catch in the late 1970's and an increase through the 1980's (Fig. 4). Trends were quite similar among the Vancouver Island, Lower Mainland, and Skeena regions but the Cariboo and Thompson regions did not display the same magnitude of change. The Keogh River trends in steelhead population size were not reflected in the catch of the latter two regions, which possess several stocks that migrate up the Fraser River as well as coastal stocks.

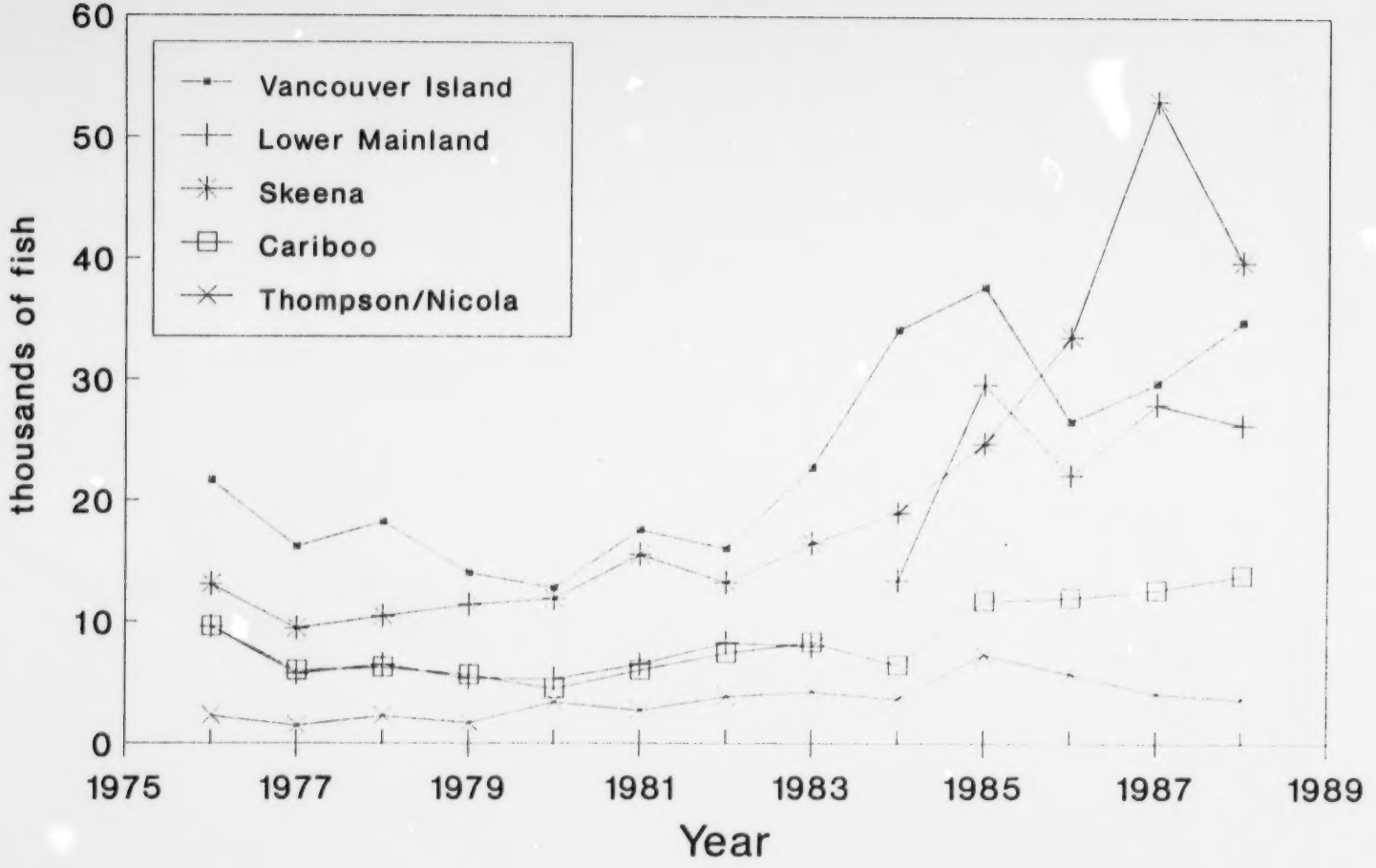

Fig. 4. Trends in steelhead catch statistics for the 1976 to 1988 fiscal years from 5 regions of B.C. with anadromous fish.

Underwater Counts from Summer-run Streams

Estimates of winter-run steelhead at the Keogh River did not provide an accurate indicator of relative run strength of summer-run steelhead on Vancouver Island. There was no correlation between Keogh population estimates and underwater counts in the Tsitika and Gold Rivers combined ($r=.39$, $p>.05$). Although the long-term trend in the combined underwater counts follows a pattern similar to the trend in Keogh population size and Vancouver Island catch, trends between counts in the Tsitika and the Gold were not consistent (Fig. 5)). However, the snorkel-survey counts on the Tsitika and Gold Rivers were correlated ($r=0.84$, $p<.001$). Underwater counts obtained from the Gold River correlated well with the high angler catch in this stream ($r=.84$, $p<.001$), even though angler catch is predominantly comprised of winter-run fish in the Gold River. Lumping the count data from the Gold and Tsitika Rivers into two year blocks to compare with Keogh steelhead estimates improved the correlation coefficient (to $r=.51$ and .67, respectively) but the relationships were statistically insignificant ($p>.05$).

Survival from Smolt to Adult

Rates of survival from smolt to returning adult at the Keogh River and at Snow Creek, Washington, were similar for four of the six smolt years examined (Fig. 6). Smolt survival rates of Keogh steelhead were only slightly higher (by differences of 0.2 to 3.8%) from 1978, 1979, 1980, and 1983. However, survival of Keogh smolts was estimated to be much higher than Snow Creek smolts from 1981 and 1982, by 23% and 20%, respectively (Fig. 6).

DISCUSSION

The steelhead populations of Vancouver Island tend to vary in the same direction between areas and the closest associations are among populations from the same geographic location. Both angler catch of the Keogh River and catch in neighbouring streams were highly correlated with the population estimates of the Keogh River. The Keogh River run size estimates largely reflected trends in population sizes elsewhere (based on catch statistics). Thus, the steelhead population estimates of the Keogh River are currently the best indicator of stock trends, despite several experiments that might have disrupted this monitoring capability (e.g., stream enrichment - Slaney et al. 1986, lake-pen rearing - Slaney and Harrower 1981).

Correlations of estimates with estimates can be spurious, leading to what has been termed the cumulative errors in regression problem (C.J. Walters, pers. comm.). Therefore, the results presented must be interpreted with

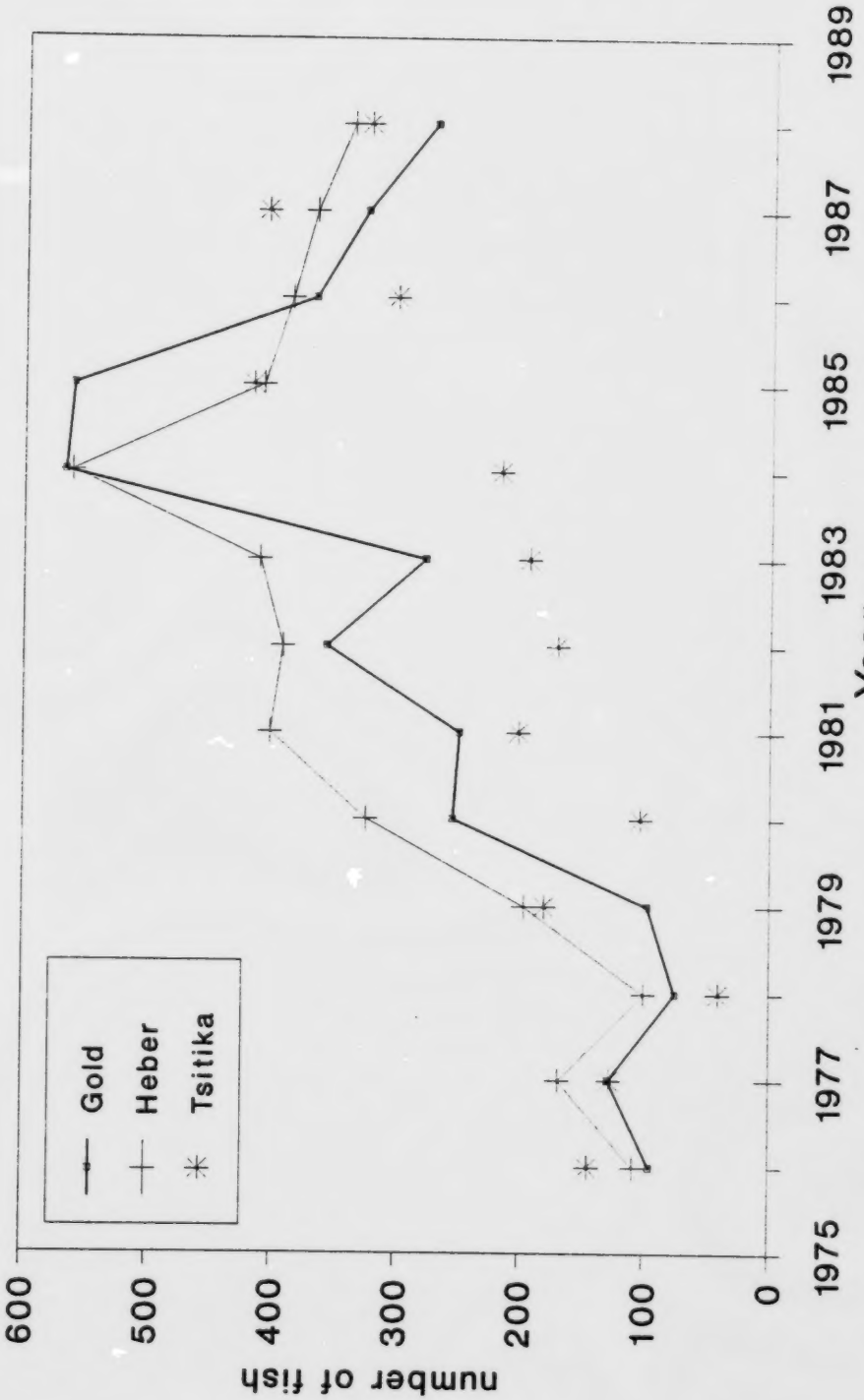

Fig. 5. Steelhead counts obtained from underwater surveys in the Gold, Heber and Tsitika Rivers on Vancouver Island for the period 1976 to 1988.

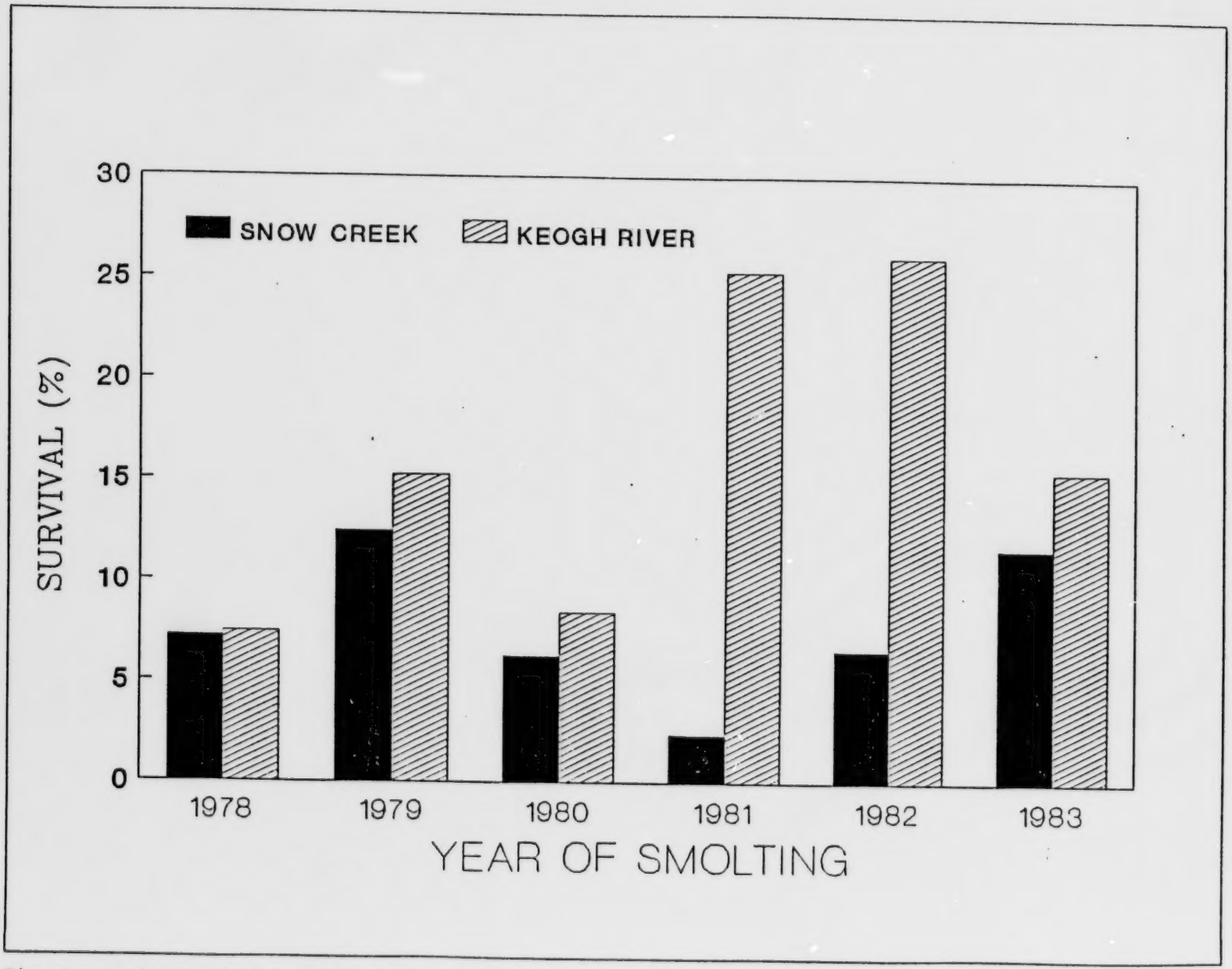

Fig. 6. Smolt-to-adult survival rate estimates from the Keogh River, B.C., and Snow Creek, Washington, for the 1978 to 1983 years of smolt emigration.

caution. For some years, confidence limits were large for the Keogh steelhead population estimate (Ward and Slaney 1988), and the within-year variation for the catch statistics found in the Steelhead Harvest Analyses were unknown. There were no replicate surveys in the steelhead questionnaire nor in underwater counts of summer run fish to provide an estimate of variance. Furthermore, the Steelhead Harvest Analysis data is collected for a fiscal year (i.e., April 1 to March 31) and is thus not a complete representation of a winter run. A portion of the catch (probably small for Vancouver Island) from a given run is thus lumped into the next year's catch for purposes related to licensing in the fiscal year.

Creel surveys conducted from 1975 to 1977 at the Keogh River demonstrated other sources of error in comparing catch statistics and population estimates at the fish fence (data on file). Angler effort was concentrated in the January to February period (70% of the effort), whereas the steelhead run lasted from November to late May. Effort was also related to flow, approximately normally distributed around a mean of about 8 m^3/sec, yet fish continued to migrate into the traps above flow levels that anglers fished. In addition, although estimate of kills and effort from this more intensive creel survey agreed with the harvest analysis results, numbers of fish released were half that reported in the Steelhead Harvest Analysis (P. Slaney, pers. comm.). Despite these potential sources of errors, population estimates correlated well with the catch in the Keogh River.

Keogh population estimates provide a further indication of an error source in the catch statistics. In 1988 the catch of hatchery and wild fish was 245 and 780 fish, respectively, representing about 1.5 fish/angler. The hatchery and wild populations spawning in the Keogh River were estimated at 281 and 1771 fish, respectively. The ratio of the catch to the population estimate is not equal. For hatchery fish there were 1.1 fish in the river for every fish caught, whereas this ratio was 2.3 for wild fish. The catch of hatchery fish may be inflated, since wild fish are probably as susceptible to catch as hatchery fish. However, this may depend on run timing which differed between wild and hatchery fish. It would be useful to assess whether hatchery fish were more vulnerable to catch, erroneously reported at a higher rate, or reported higher due to the combination of run-timing and reporting in the fiscal year.

Some of the uncertainty from these data might be reduced. To improve the monitoring capability of the Keogh River, errors in the population estimate must be reduced. The commencement of adult fish trapping has become later in the steelhead season. In years of abundant early-run fish, the population size is known with less confidence because of the low rate of recaptured kelts relative to new (unmarked)

fish. We currently attempt to mark early-run fish by angling, but realize this has inherent biases. Trapping the entire season would be 2 to 2.5 times more costly, but in at least 4 of the 6 months fish marking is required. Reducing the error factor in the Steelhead Harvest Analysis would also be costly. Any change to the current technique of the Steelhead Harvest Analysis would require calibration to maintain the data base already established.

There was a stronger correlation between Vancouver Island catch and Keogh steelhead runs prior to the change in regulations to catch-and-release and the introduction of hatchery fish to Vancouver Island (early 1980's). This occurred when there was also an oceanographic event that likely altered survival rates for steelhead in the ocean (Ward and Slaney 1988). The angler response to the shift to restrictive regulations was a decrease in angler participation (Billings 1988) (Fig 2). This decline was brief in duration, however, since the combined effect of increasing abundance of hatchery fish and improved wild return rates invoked an increase in angler interest. The catch per unit effort has increased, as has the catch in the Keogh River (41% from 1984 to 1988, 17% from 1976 to 1983). The regulation changes, hatchery fish introductions, improved survival rates, and anglers' sociological responses combine to produce an unknown effect on steelhead catch statistics. This and the large variance in the Keogh population estimates in some years may explain the poor correlation between wild catch on Vancouver Island and Keogh run size unless years were blocked into groups of two.

Six eastcoast streams on Vancouver Island were selected to represent winter-run populations. Four of these streams (Salmon, Nanaimo, Oyster, and Englishman rivers) have been associated with habitat degradation and high angler exploitation. Perhaps steelhead stocks in these streams have not recovered as quickly as others following the change to catch-and-release regulations. In addition, survival in the ocean for these populations may not have improved as much as northern Vancouver Island streams. When the data for steelhead seasons was lumped in two-year groups, the combined catch from these streams was significantly correlated with Keogh runs only if the 1985-86 years-group was excluded. Coincidently, these data (1985-86) represent returns of fish that were resident in the ocean during an anomalous (ENSO) oceanographic event (Ward and Slaney 1988), discussed later, which may have produced dissimilar conditions for survival between stocks.

Further indication for a geographical difference in returns was evident by comparing the results of the correlation analyses from two relatively large streams, the Nimpkish and Cowichan rivers. The catch statistics from the Nimpkish River, on northern Vancouver Island, were highly

correlated with Keogh River run strength, with the possible exception of 1987 returns, whereas the more southerly Cowichan River provided catch statistics that showed no correlation with Keogh population size unless years were blocked by 2-year groups and, again, the 1985-86 data point was excluded. Differences in the size-adjusted survival rate in the ocean are suspected in some years between northern and southern stocks.

The number of fish observed in underwater census on the Gold, the Heber and the Tsitika rivers has increased since 1975, with some decline after 1984. Only for the Gold River were these counts of summer-run fish positively correlated with catch of fish there. No catch data exists for the Tsitika. The winter run of the Keogh River was poorly correlated with these summer runs. However, as for the catch data for Vancouver Island, trends were similar. There is a need to verify the counting efficiency of the underwater survey method for steelhead similar to the work of Slaney and Martin (1987). On Vancouver Island, summer-run fish are generally from the same year as smolts as fish returning in that winter run, e.g., smolts of 1980 return mainly as .2 winter-run fish in 1982, whereas summer-run fish tend to be older (Hooton et al. 1987), and thus will be .2+ when counted during the summer or fall of 1982. However, there is much variability in age at return (Billings 1988, Ward and Slaney 1988) which would obscure any attempt to relate summer and winter runs. Furthermore, summer-run stocks are intercepted more frequently in the commercial salmon fisheries (Evans 1979). Recently, Light (1987) provided evidence that summer-run stocks are also more heavily intercepted than winter-run fish in the open-ocean fisheries.

The survival estimates of Keogh River and Snow Creek smolts of 1978, 1979 and 1980 were similar. The 1981 and 1982 smolts did not survive at similar rates from the two streams. The larger size of Keogh smolts in 1981 (Ward and Slaney 1988) may explain the higher survival from that group, along with added mortality from fin-clipping and anaesthetic use at Snow Creek (R. Cooper, pers. comm.). The difference in survivals from 1982 smolts cannot be explained by size or fin-clipping mortality and we suggest that the difference may have been due to altered conditions in the near-shore marine environment (Ward and Slaney 1988, Ward et al. 1989 in press). Whereas El Nino conditions for Keogh steelhead, which migrate into Queen Charlotte Strait, may have improved chances of survival, the opposite may have been the case for Snow Creek smolts, which migrate into Juan de Fuca Strait. This may also explain the relatively lower catch in southern Vancouver Island streams. Alternatively, there is no relationship between smolt survivals at the Keogh River and Snow Creek. Further data collection is required before reaching sound inferences from these survival estimates.

Regardless of manipulations at the Keogh River (hatchery fish and stream enrichment), survival of the 1983 smolts differed by only a small percentage between the two streams. Both streams should continue to provide survival data in both fresh and salt water which will assist in understanding the dynamics of steelhead production on the Pacific coast. Each system appears to be a reasonable representative of smolt-to-adult survival rates within respective oceanographic areas, and this should be investigated further.

SUMMARY

Despite other enhancement manipulations in the past at the Keogh River, its population and survival data provided a reasonable indicator of trends based on comparisons of catch data and survivals elsewhere. With the recent termination of hatchery releases and the stream enrichment experiments, the monitoring role of the Keogh River should further improve. However, the estimate of run size should be improved for early-run fish to maximize accuracy.

It is evident that the catch statistics from the annual Steelhead Harvest Analysis have been affected by regulation changes and the introduction of hatchery fish, and that catch-per-unit-effort has increased in the last five years. Fisheries managers in British Columbia have gained insight into the status of steelhead populations by collecting catch statistics, conducting underwater surveys, and utilizing Keogh population monitoring. However, the magnitude of error is not reliably known in the former two methods. Therefore, the latter, as a single B.C. index river for wild steelhead, provides a useful long-term indicator of stock status and smolt-to-adult survival as part of the ongoing research into the freshwater and marine life history components.

MANAGEMENT RECOMMENDATIONS

1. Continue steelhead survival monitoring at the Keogh River, particularly important considering the unknown effects of the open-ocean fishery (Light 1987) and global warming predictions (Meisner et al. 1988).

2. Implement steelhead smolt enumeration and sampling at a southern Vancouver Island site, possibly French Creek (cooperatively with Fisheries and Oceans - Bocking et al. 1988) or Goldstream River. Survival estimates should be compared with Snow Creek to test its index strength. Similar studies might be considered in the Skeena and Fraser drainages, although fishery interceptions could confound the results. Smolt sampling may, at least, provide an indication of size variation, known to affect survivals (Ward and Slaney 1988, Ward et al. 1989 in press).

3. Improve the calibration of the Steelhead Harvest Analysis by utilizing creel cards and roving census similar to that used by Hooton (1978), Hooton and Lewynsky (1985) and Clark and Facchin (1986). Surveys should be continued over several years and conducted simultaneously on different systems, with rotation at 5-year intervals.

4. Assess the catchability and incidence of repeat capture of wild versus hatchery steelhead adults. This will require population estimation and intensive creel survey and might best be attempted at the Keogh River.

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Appendix 1. Keogh River steelhead population estimates, catch statistics and underwater census data from 1976 to 1988 used in the correlation analyses to test the Keogh River as an index system.

		Catch Success by River				
Year	Keogh Run Size	Keogh	Quatse	Cluxewe	Nimpkish	Salmon
1976	859	195	444	112	581	319
1977	625	105	345	30	210	538
1978	706	186	243	224	340	295
1979	299	39	68	53	219	369
1980	209	26	82	168	148	303
1981	608	81	33	71	533	520
1982	938	171	39	107	525	398
1983	2730	306	97	725	1184	952
1984	1344	497	120	699	1208	158
1985	580	286	65	484	652	235
1986	1243	244	167	155	701	167
1987	2938	1572	350	463	541	402
1988	1730	780	590	261	669	1016

	Oyster	Englishman	Nanaimo	Cowichan
1976	261	569	1941	2687
1977	220	527	1150	1339
1978	108	445	1263	2279
1979	265	761	1632	1981
1980	195	277	853	1229
1981	291	382	982	1849
1982	264	329	829	2436
1983	399	750	1081	1746
1984	472	952	1139	4087
1985	1086	1886	1851	6300
1986	447	907	883	4236
1987	412	948	1363	2867
1988	420	1169	1490	7001

	Underwater Census	
	Tstitika	Gold
1976	144	95
1977	127	128
1978	40	75
1979	180	97
1980	103	254
1981	201	249
1982	170	357
1983	193	277
1984	216	567
1985	417	561
1986	301	367
1987	406	326
1988	324	271